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Research on Complex Decision Making, Knowledge Representation, and the Transfer of Existing Systems to ARI

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for

Contracting Officer's Representative
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Basic Research
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This report briefly describes the results of a program of research that focused on the conversion of a new technology into a form that is facile and generally transferable using a network of microprocessors. When the contract was awarded, the choice (at that time a very reasonable choice) of hardware was the 8-bit microprocessor and (standard to ARI and other institutions) the Apple II microprocessor, augmented by standard peripheral equipment.

The program suites, appropriate to these machines and a Corvus 20 Megabyte Disc, have been delivered, as originally specified. Now it is true that a 16- or 32-bit technology would have been a better choice since obvious limitations and difficulties crop up with smaller address space. However, the networking paradigm remains viable and may only be replaced by a multitasking system with very sophisticated display and control capabilities to exhibit the power of the systems to any user and render the computing organization transparent, as is required.

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18. SUBJECT TERMS (Continued)

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19. ABSTRACT (Continued)

The deliverables noted are CASTE (Course Assembly System and Tutorial Environment), THOUGHTSTICKER, and the Team Decision System (TDS), together with manually and computer-administered versions of a test for learning innovative and conceptual style, SPC2.

In addition, documentation, source code, and various other documents have been delivered.

While the program emphasized the transfer of a rendered-transportable-technology, it encouraged the dissemination of knoweldge and further research. Both of these objectives have been satisfied to the extent required in the Annexes to this report.

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RESEARCH ON COMPLEX DECISION MAKING, KNOWLEDGE REPRESENTATION, AND THE TRANSFER OF EXISTING SYSTEMS TO ARI

EXECUTIVE SUMMARY

This report briefly describes the results of a program of research that focused on the conversion of a new technology into a form that is facile and generally transferable using a network of microprocessors. When the contract was awarded, the choice (at that time a very reasonable choice) of hardware was the 8-bit microprocessor and (standard to ARI and other institutions) the Apple II microprocessor, augmented by standard peripheral equipment.

The program suites, appropriate to these machines and a Corvus 20 Megabyte Disc, have been delivered, as originally specified. It is true a 16- or 32-bit technology would have been a better choice since obvious limitations and difficulties crop up with a smaller address space. However, the networking paradigm remains viable and may only be replaced by a multitasking system with very sophisticated display and control capabilities to exhibit the power of the systems to any user and render the computing organization transparent, as is required.

The deliverables so far noted are CASTE (Course Assembly System and Tutorial Environment), THOUGHTSTICKER, and the Team Decision System (TDS), together with manually and computer-administered versions of a test for learning innovative and conceptual style, SPC2.

In addition, documentation, source code, and various other documents are deliverable products.

While the program emphasized the transfer of a rendered-transportable-technology, it encouraged the dissemination of knowledge and further research. Both of these objectives have been satisfied to the extent required in the Annexes to this report.

1. Outline

This report is organised as follows:

Section 2. is an introduction to and an overview of the work done. It provides the rationale for integrating the various products.
Section 3. deals with THOUGHTSTICKER 1.0
Section 4. deals with TDS 1.0
Section 5. deals with CASTE 1.0
Section 6. deals with SPC2
Section 7. deals with rules for authoring which must be respected if the proper person/machine/interfaces are to function satisfactorily given screen display and a few other limitations of D/CASTE/1.0. These do not bear upon the underlying software implementation.
Section 8. is a summary of immediate further research using the existing systems delivered, but enhancing them.
Section 9. Is an overview of theoretical work undertaken and disseminated by book chapters, by papers and conference presentations.
Section 10. is a review of further deliverables for the most part already delivered.
Section 11. is an account of presentations or publications that satisfy the requirement for the dissemination of knowledge.

RESEARCH ON COMPLEX DECISION MAKING, KNOWLEDGE REPRESENTATION, AND THE TRANSFER OF EXISTING SYSTEMS TO ARI

2. Overview and Introduction

Over a period of about 7 - 8 years various human machine systems were designed and implemented under the whole or part support of the ARI, through the European office, to System Research Ltd., U.K. (the degree of sponsorship depending upon the system in question). All of them are founded in Conversation Theory and its protologic Lp (described in Annexe 1.; an ECTJ invited review paper) and in one of the products; a "Primer" on the background.

One of these systems, CASTE, is a sophisticated tutorial environment. It provides, in the first place, an accurate and externalised record of how learners acquire concepts which are represented, together with their relations, in a so called "entailment mesh". The learnable concepts represented in the mesh consist minimally of one (often several) executable models: a description or behaviour (obtainable by executing a model and a reference name such as "Vessel" or "Friendly Country X" or "Country Y" or "Routes from X to Y" or "Commander of Platoon".

A model may be

> (a) one or more computer programs acting upon a specified domain

> (b) a working equipment (for example, a computer traced laboratory for performing statistical or physical experiments); this equipment must be able to trace, evaluate and return a numerical index of user performance.

> (c) a series of conditions and instructions that determine a role, for example, the role of "Commander" in such a way that enactments can be evaluated by a person (usually a group of other learners, provided that certain essential restrictions built into a program are satisfied) and the evaluation returned in numerical form to CASTE (for example, by measures on a repertory grid scheme).

In all cases (and (a), (b), (c) are not exhaustive), the model must be able, on CASTE demand, to give a demonstration

of how the concept is applied (to make or do or recognise some objective) and, conversely, to accept and to evaluate an explanation from a learner and so to give CASTE an indication of how the learner uses or understands the concept in question.

As noted already, concepts are related in a "mesh". This mesh (also known as an "Lp statement") answers the why question, in contrast to the how question ie. it gives an answer to the question "why did you use that method or give that explanation" or, with equal significance "from what other concept can the concept that a learner is dealing with be derived." Such entailed derivations specify how one concept model (which is executable, which works) can be built out of other concept models. If and only if a learner can give satisfactory replies to the what and how questions is a shared concept said to be understood and is, on empirical grounds permanently resilient.

Usually there are many possible derivations specified in an entailment mesh, structured, for example, by a group of experts. Further, there is no reason to limit the number of shared concepts which might be invented and which do work, equally well.

Consequently, CASTE contains not only a facility for recording the process of learning in great detail. It also has authoring facilities that are at the learners disposal provided no part of an originally satisfactory mesh is deleted. In this way a mesh can and, in practice, does evolve. In principle, CASTE could be initialised with a blank mesh (although this expedient is not usually recommended except in special applications); for example, where learners have prior knowledge of a domain (for instance, of how to manouver or allocate resources in an uncertain situation).

Finally, CASTE is often augmented by specific tutorial aids. It has been found in numerous experiments that learners have individually preferred strategies of learning such as following one route assiduously or, on the other hand, building up a global picture and completing detailed task accomplishment later. Again, some learners are able to use exact analogies; to use valid generalisations to learn exemplars, or conversely, to move from exemplars to a generalisation.

Such tendencies, whether manifest over many learning situations or context specific, come out as one component of a learning record. Hence, one tutorial heuristic employs

this learning strategy information to recommend paths that are likely to render subsequent learning effective for the learner in question: in the limit case, to dictate that certain paths are taken (this, however, is seldom recommended; some measure of choice is needed if only because these learner propensities or styles are, in general, context dependent).

Another readily implemented tutorial heuristic stems from work done by my team, 20 or 25 years ago, on complex adaptive training systems which matched task difficulty to proficiency in order to achieve a balanced learning condition. Translated into CASTE terms, this heuristic ammounts to uncertainty regulation; maintaining enough degree of choice, but not too much so that both overload and boredom are avoided. The balance point, for a particular learner, is again set by data from the historical record.

CASTE, used in a tutorial mode, provides (or is initialised) with a representation of shared concepts (minimally specified above). These concepts are inscribed in an entailment mesh which also consists in relations that connect them together and the entire mesh is open to non deleting evolution (by further concepts and/or relations). There is a precise sense (as noted in the referenced annexes) in which:

> (a) All the relations or "entailments" represent logical coherence of the "< process, product > or < Execution of Model(s), Product (description or behaviour) >"pairs minimally representing shared concepts and
>
> (b) The Model (Process) aspect of a shared concept crystalises the answers to a how ("by what method") question in a conversation through CASTE between participants in the conversation. The products answer what questions ("what is the conversation about") and the relations between concepts answer the "why" questions ("why did you use this method and I use that method").
>
> (c) Hence, a mesh is a representation of knowables and an open-to-mesh evolution theory about what may be known.

Between 1974 and 1975 it became clear that a mesh of this

type is more than an inscription. Rather, it embodies a calculus, the protologic, Lp, of conversation theory and is manipulable. For example, inferences can be (and, in real systems, are) made to propose further coherencies, subject to the overriding rule that originally asserted distinctions between concepts are neither obscured nor denied.

The next product, THOUGHTSTICKER, operates in the CASTE environment to perform basic protological manipulations upon the mesh. The THOUGHTSTICKER operations assume that any shared concept is such a thing; either, it has an executable model, or one will be provided using the "Configure" Routine which is continually available in CASTE; taken together, THOUGHTSTICKER and the "Configure" Routines form an authoring mode and a learner may occupy the position of an author, as desired.

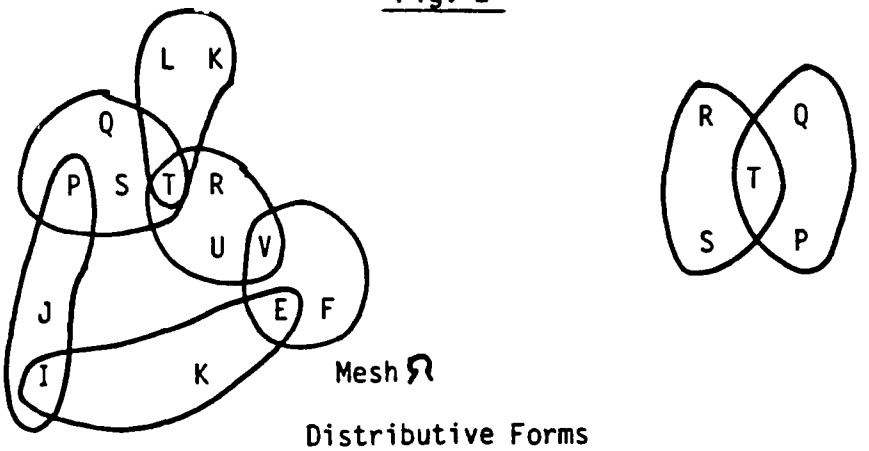
Before describing these operations in outline it should be noted that although previous statements that all entailment relations are of coherence (of concepts) and preserving the distinction (of concepts said to be distinct), there are usefully demarcated varieties of relation. A collective coherence means that certain concepts stick together; any one being derivable from the others (Fig. 1.) If (as usual) several derivations of a concept are possible the coherence is distributive upon the concept in mind and this fact is represented in Fig. 2. (using coherencies that overlap). Provided that no distinction is lost both coherence and distinction act as short range attractors and deflectors between concepts. On the other hand, an analogy, which involves a coherence - similarity and a distinction term, are a long range attractor and deflector pair. Generalisation is a special unidirectional analogy: all of the exemplars are encompassed by the generalisation but are only partly analogous to it.

With this preamble and recalling that a shared concept is minimally a process, product, pair it is possible to outline the THOUGHTSTICKER operations carried out on a mesh. Of these, two are directional unfoldments of a mesh to produce ordered structures from a specified point of view (representing learning strategies or strategies of planning and action). The first of the two is called a "Prune" operation (Fig. 3) and the next is a selective pruning (Fig. 4) which dissects the class of all learning or action sequences, as the case may be, into specific conditional and program like structures that are all open to execution. Some caution is needed insofar as the execution may be initiated after several stages as indicated below (in the case of generalisations). Hence, it is better to consider "Prune"

Fig. 1

Collective Coherences

Fig. 2



Distributive Forms

Fig. 3

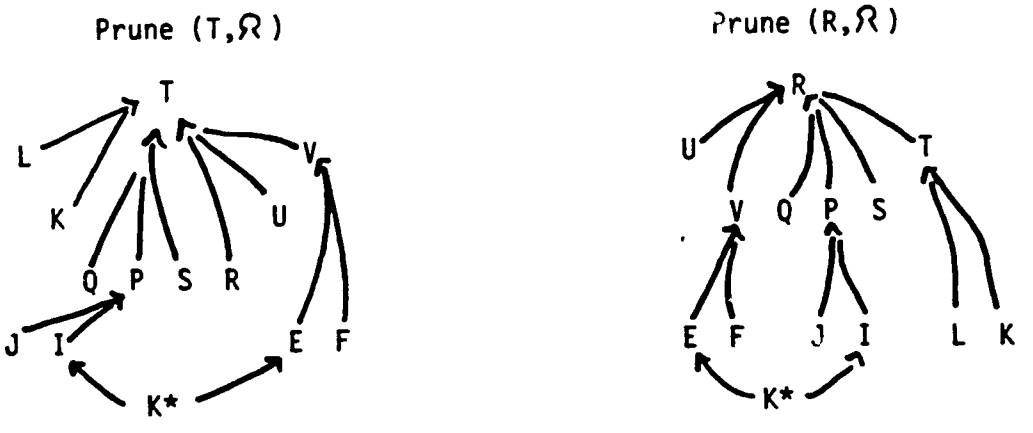


Fig. 4

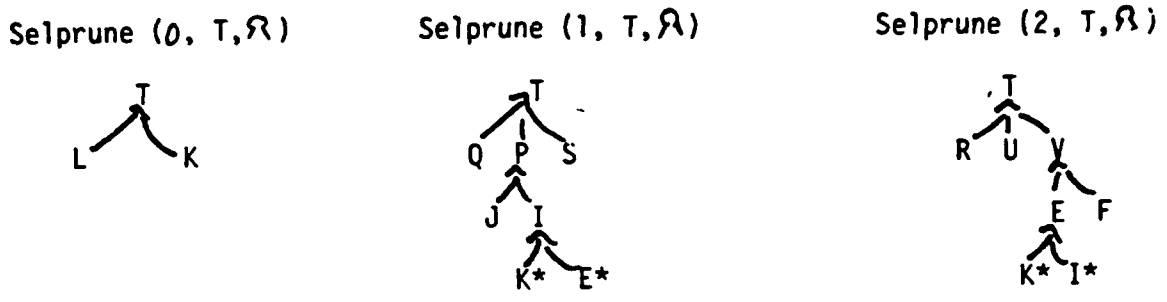


Fig. 5

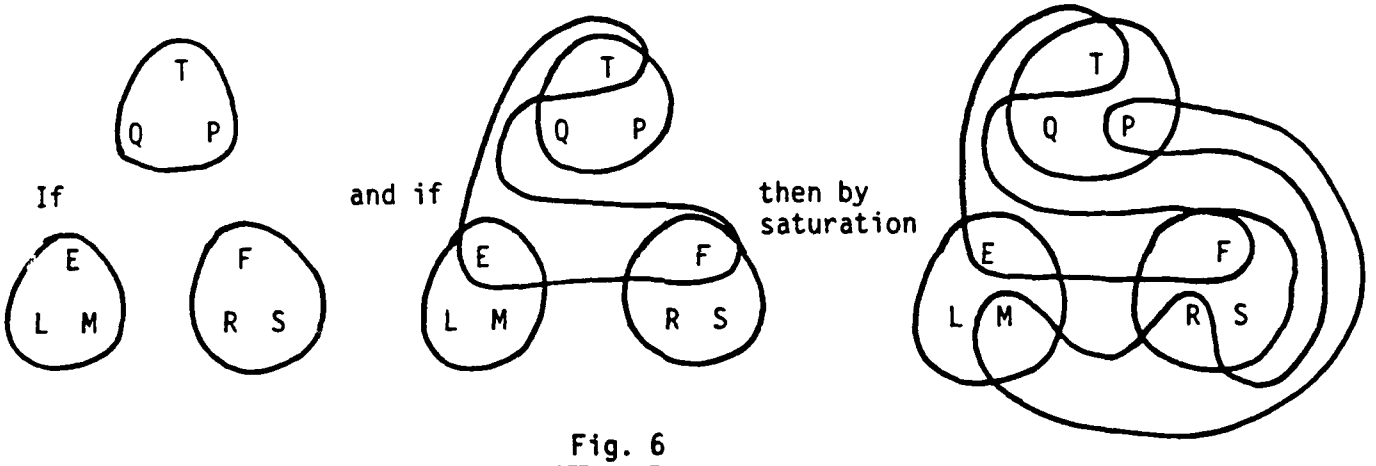
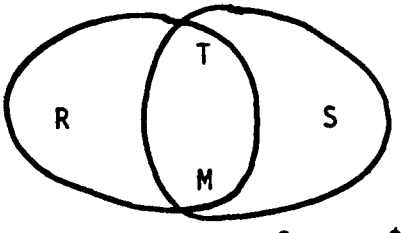


Fig. 6



Genova Contravention

and "Selprune" conjoined to execution in terms of an iterative operation "Expand" represented and implemented by (the n fold iteration) of a sequence like.

"Prune (from some concept); ((Select (Selprune)); (Execute to Model)"; that is, although any shared concept has an executable model, this model may be and often is a mesh, the shared concepts of which may either point to other meshes or directly and with equal legitimacy to models.

The next THOUGHTSTICKER operation is "saturation" (Fig. 5), which is an inference rule, appliable if and only if a sufficient number of distributive coherencies exist. If so, then "saturation" proposes further coherencies that do not loose already asserted distinction between shared concepts that are Lp legal. The author or team of authors may, of course, deny or accept these proposals, in which case the number of proposals is greatly reduced.

"Pruning" and "Selective Pruning" are forms of unfoldment and, thus, of Lp legality criteria. If a mesh is "prunable", then it is legal; if not, then it is either modified or transformed.

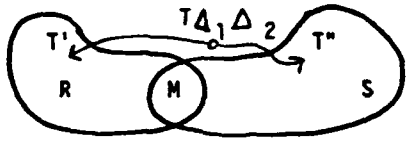
The crucial point is loss of distinction as manifest in the "Rule of Genova", named after Vittorio Midora and George Olympia and Renaldo Sana (of whom Vittorio worked for a year or so in my own laboratory; Olympia visited often, and in those days, Renaldo Sana headed the CNR group in Genova). The least elaborate case of conceptual conflict and its resolution is shown (in condensed form) in Fig. 6. Conflict resolution ammounts to analogy creating and generalising actions. These are shown (as outlines) in Fig. 7 (various analogy productions) and in Fig. 8 (for generalisations) and for generalisation resolution in Fig. 9.

It may be added that one entailment mesh can be and usually is quite large. In addition, it is often necessary to deal with distinct meshes related by analogy and/or generalisation, shown in Fig. 10 and in Fig. 11. So, finally, there is an interesting situation in which the combination and continued, iterative, application of these Lp operations lead to an emulation of personal concept production and reproduction in Conversation Theory.

The notion of emulating personal concept production is spelled out in Section 9. Theoretical work has led to a concurrent algorithmic specification of a considerable reapraisal and enhancement of the protologic, Lp, of Conversation Theory, C.T.

Fig. 7

If unchanged then any of these is a resolution:



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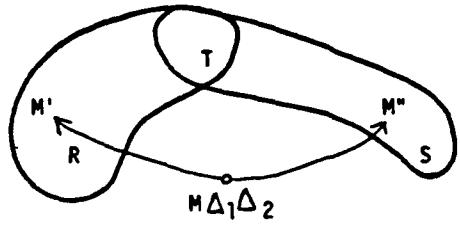


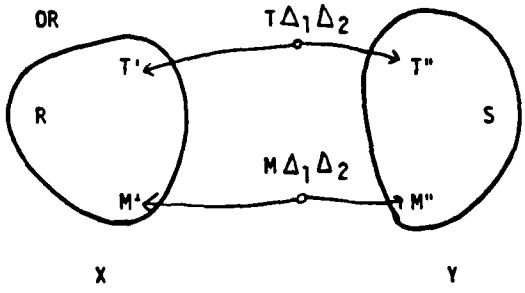
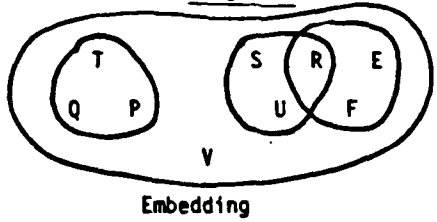
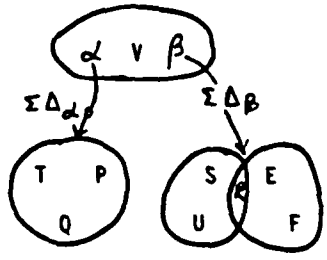


Fig. 8



Embedding

Fig. 9



Resolution and Generalisation

Fig. 10

Distinct Meshes

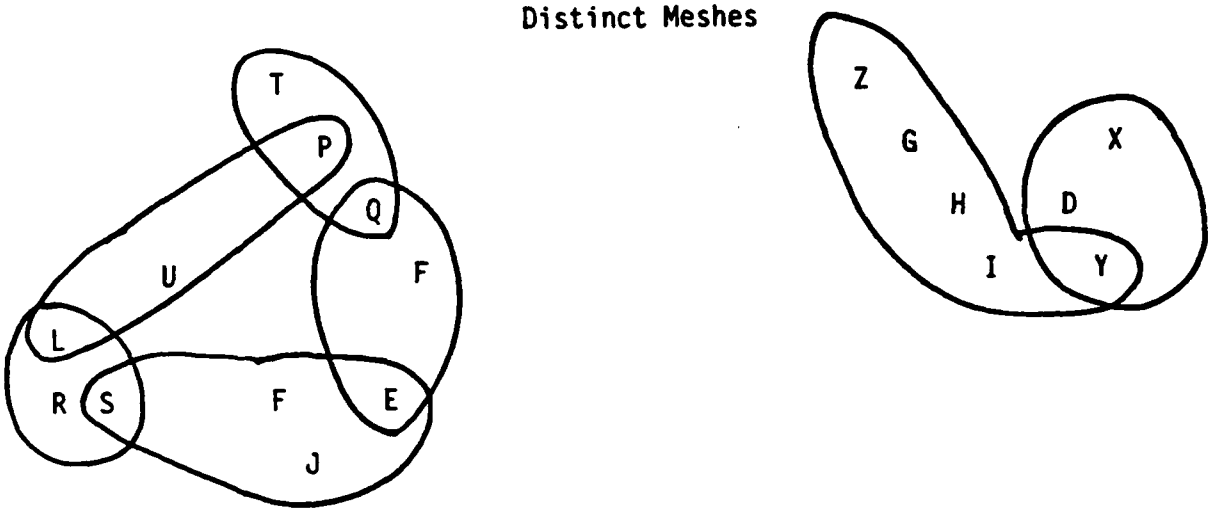
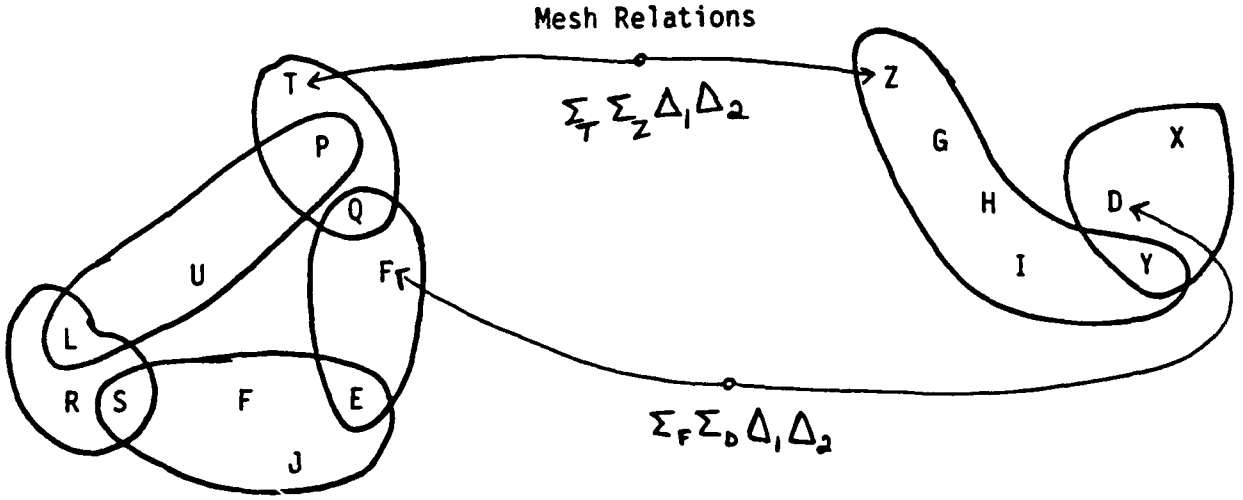


Fig. 11

Mesh Relations



In order to avoid repetition (some readers are already familiar with Lp and its C.T. basis, some are not) the Appendices include a recent invited review paper so that readers who are not happy about the Lp and C.T. postulates (whether in accord with them or not) can consult it as a preface to Section 9.

3. THOUGHTSTICKER Version 1.0

As noted already an entailment mesh is a class of expressions in the protologic, Lp, of C.T. and specific assumptions are made (notably, a model is an integral part of any shared concept or "topic" in the entailment mesh). Unless the assumed requirements are satisfied, Lp operations carried out on topic names and relations are arbitrary string manipulations. On the other hand, if these requirements are satisfied, then operations upon topic names are meaningful. The use of THOUGHTSTICKER 1.0, which treats topic names as though they designated shared concepts is thus only sensible if names said to indicate concepts do, in fact, designate a sufficient exteriorisation (minimally an executable model and a product) of a shared concept ie. if the what, how and why questions of Section 2 have been posed and answered satisfactorily.

From a users point of view it would be obsessive to require that all models exist when THOUGHTSTICKER 1.0 is used. It is sufficient to be certain that they will exist before the mesh is used by a learner or another author. In practice, some authors start with many models fully specified; others from an overview of a subject matter or skill and the rational conviction that models (perhaps hazily in mind) can be refined and implemented. But, in any case, authors must be aware of those requirements. Lacking the awareness, the use of THOUGHTSTICKER 1.0 is logically unsound and often counterproductive as experience has amply and frequently shown.

It is worth exemplifying this point, in order to give it the emphasis needed. To do so, take a mathematically precise subject matter; conveniently part of "statistics", where there is no serious ambiguity at all (this is not to suggest that THOUGHTSTICKER 1.0, let alone Lp, is restricted to such subject matter domains).

Let V = Variation
S = Scatter (of a numerical quantity about an average value)
M = Mean of n quantities U
D = Distance (numerically) from mean
D2 = Squared Distance
Z = Modulus (positive value) of D or B (below)
B = Numerical distance (from average

value)
A = Average (or median or mean)

Suppose,

(a) V is derived, by entailment from M, D and D2
(b) V is derived, by entailment from A, B, Z and S

Given (a) one possibility is
V = Sum D2/n
D2 = D Squared
D = U - M

Given (b) V = one kind of S, and from average median or mean (S,Restricted by R.M.S. distance)
S = Sum Z/n
Z = Modulus U - A

Clearly, both of these and many others can be modelled and the model of V obtained as something generating either S or (the usual) variance. If we wish to obtain standard deviation then any derivation must have a form that makes sense of only variance by pointing out, for example, the restrictions of the more usual (but less intuitive) variance. However, both of the derivations of V make sense and (at the cost of less convenient forms of distribution) have statistical merit. The simple derivation of the standard deviation from V points to the rationale of adopting variance as an index of variation, V, and also for certain any other indices of variability, for example, several that are used in non - linear domains and, as a matter of fact, some non - parametric piecewise continuous or only ordered statistical methods. The fact that this rationale is often omitted indicates the strength of Lp and of THOUGHTSTICKER 1.0 if properly employed. It is easy enough to cite inefficiencies or even disasters that might have been avoided if responsible, trained personnel had thought, rather than reacted, to a superior's requirement "Tell me, what's the variability of those figures" by the tacitly acceptable "That guy wants a variance" which was duly calculated on a pocket calculator and phoned back.

With this essential preamble, THOUGHTSTICKER 1.0 is able, apart from display, mesh recording and the like, to perform the following Lp operations reliably.

(1) Pruning from any specified topic
(2) Selective pruning of a given pruning
(3) Retrieving meshes
(4) Saturation
(5) Rule of Genova contravention or lack of asserted distinction
(6) Various dependent operations such as topic listing and cluster listing, alphabetic display, level display.

These operations are described in Section 2 using the same framework. But, preferably to ensure that the emphasised conditions are satisfied; they should be carried out in the environment of CASTE 1.0 where it is possible to add currently specified algorithms as programmed implementations that greatly enhance the value of the system.

4. TDS, the Team Decision System, implemented as TDS 1.0

The purpose of the team decision system is to provide a very general C3 training and operation simulating system. various configurations were developed, tested and used during the middle and late 1970's and this development, at the laboratory of System Research Ltd., Richmond, Surrey, U.K. was in large measure tailored to incorporate the findings of 4 Richmond Conferences, on complex decision making in C3, sponsored by the ARI and organised by System Research in consultation with the European office of ARI and the U.S. ARI. The findings which came from these conferences were of immense value in specifying the essential requirements of a complex C3 situation and, thus, forming a specification for TDS, in the course of its construction and, later, its experimental trials in the laboratory which yielded several interesting results.

From the outset it was recognised that TDS should be and was an elaborate modelling environment for CASTE used in a tutorial or training mode. Using the objects and actions that are the elements of TDS it is possible to demonstrate and to explain a large number of models of many different kinds; for example, of manouevers by one or many craft, of tactics and the like. Similarly, the expertise of competent users can be represented in Lp, as one or several entailment meshes which, if unfolded, give rise to plans or the performance of tactics. This act may be the reaction to an emergency (for instance, that a craft is incapacitated due to lack of fuel or that a trading route is disrupted); An automatic reaction if the users are unable to deal with the emergency in question.

There are several unique aspects of the team decision system, if contrasted with other C3 simulations.

> (a) Each commander (or user) has the role of a mercenary able to compete and/or to cooperate in the pursuit of a common mission which is to minimize the density of "intruders" or "marauders" that enter an environment and gradually converge upon trading routes where they are destined to demolish tradir vessels upon which the viability of this environment depends.

(b) Each mercenary commander, or user, is required to divide attention since each one controls at least 2 craft by assigning them tactics that are subsequently executed (failing interruption) so that the craft are quasi autonomous (in fact, 2 microprocessors running quasi independently in a simulated environment of trade, economy, geographically located bases and so on).

(c) Each craft, instructed by a commander, acts upon partial information about the environment. This partial information is displayed to the commander/user to whom it belongs, through a local display, craft at centre, periodically updated.

(d) All actions, such as moving a craft or using it to demolish an intruder/marauder has a cost, in terms of fuel or some other conserved quantity.

(e) The possible actions include obtaining up to date but specific information about the simulated environment. The cost required is deducted from the fuel available to the craft in question. At a critical minimum level the craft is lost.

(f) The overexpenditure of energy/fuel by a commander/user in demolishing an intruder leads to a "hole" in the quasi spatial "environment". Such holes impede navigation of craft or trading vessels and are particularly harmful to the environmental economy upon which the supply of fuel depends. In this case a frequently competitive liason must become cooperative since at least a pair of craft must be placed in the vicinity of the hole in order to repair it.

Many of these features have been incorporated into the del vered deliverable TDS 1.0. All of those outlined in (a) to (f) of this section are capable of incorporation (recording and

rerun of session included) under a proposal for an augmentation of the existing TDS 1.0 using the existing configuration of standard hardware. These augmentations are desirable in view of their low cost and their upward compatibility with nowadays standard but more sophisticated equipment; hence, their transferability.

5. The Course Assembly System and Tutorial Environment C/CASTE/1.0

It proved difficult to implement a satisfactorily transferable and transportable version of the original CASTE. In part, this is due to the relative inflexibility, for this purpose, of standard computing equipment. To a large extent that barrier has been levelled out by currently available computers and more versatile peripheral equipment. In part, however, the difficulty was exacerbated by persistent misperceptions; perhaps the most irritating is crystallised in the phrase "text explanation"; namely, a string, with luck "a description" but seldom explaining anything, let alone in a manner that can be evaluated.

The history of these misperceptions is recorded in my files. They are neither a sign of wilful glossing nor of ignorance but interesting exemplifications of how hard it is to communicate some very simple ideas, once that they are mistakenly conceived to be complex and ineluctable ideas.

A version of CASTE, stripped of the just - noted - misperceptions was demonstrable at quite an early stage. It was, in fact, demonstrated during a site visit. But it had several unacceptable (although not - too - obvious) imperfections upon deeper scrutiny (for the record, it consisted in modelling facilities in quasi independent computers attached to the at - that - stage existing implementation of THOUGHTSTICKER 1.0). Bringing the imperfections into focus, the system with its microprocessors interacting through CCS communication cards only, was "hard programmed" (by analogy with "hard wired") to operate with models in one and only one subject matter domain. It was, furthermore, inherently unreliable due, in part, to hardware deficiencies and, in part, to lack of a hard disc communication system such as the CORVUS and OMNINET acquired later.

The delivered CASTE is, at least in principle, devoid of these flaws. It has a very comprehensive recording facility (provided that printout of history is obtained at each session, quite rationally only the current status of a user is retained, otherwise). It is chiefly due, as are several improvements in the original 1979 design, to Charles Small and his colleagues who, in fact, based their design specification upon an intelligible Lp mesh representation. The system runs with perfectly acceptable rapidity on the

CORVUS, Omninet and a minimum of 3 Apple 2e microprocessors, together with random access slide (or random access tape or video disc) and dot matrix printer peripherals. It is very reliable and offers comprehensive model configuring capabilities for arbitarily selected subject matters. File space is readily assigned to different users. The software architecture uniquely captures the architecture of the most advaanced original. It is reliable and well documented in Jaworski's ABL/W/4 as are THOUGHTSTICKER 1.0 and TDS 1.0.

My colleagues and I have proposed, in concert with this software engineering designer, upgrading of C/CASTE/1.0 to CASTE 1.1 and CASTE 1.2 which have been developed algorithmically but not, as yet, implemented. These are upward compatible with more advanced technology. These augmentations go as far as practicably possible to upgrade a very complex system, such as CASTE, within the limits of 8 bit microprocessors and include a proper handling of analogies and of generalisations; also, the more important types of "negation" or, more accurately, of "exclusion" principles which have been developed in our theoretical work. Finally, automatic model configuration by an author mode user or team of users has been extended beyond the compass of the present options.

6. Stylistic Tests

Due, in large measure, to my unavoidable absence for several bits of major surgery in the U.K. (where I have a private insurance policy which allows for rapid surgical processing) certain curiosities have beset the development of the promised tests for learning, conceptual and innovative style. In fact, an earlier version of a stylistic test (an experimental version retranslated, in fact, from its Dutch translation and from its Italian translation) has been programmed for automatic administration. In fact, also, the most recent version of this stylistic test had already been delivered, readjusted for use with a North American population; the evidence strongly indicates that even the best European version gives inadequate emphasis to the creative or inventive, (in contrast to the rote recall), intention of the test. The cleaned up and "tuned" to induce a properly creative "mental set or attitude" version has been delivered already in a manually administered form. A computer program which performs the onerous chores of scoring and of retaining full information in raw score vectors (so that various, equally valid, scoring schemes can be used later) is a delayed but forthcoming delivery. The manual test is "SPC2", the programmed form is "SPCP2".

The purpose of the tests is to determine an anticipated style (to parameterise tutorial strategies in CASTE or to predict types of creative and leadership potential, notably in TDS). There are other possible applications and a recent proposal to the ARI concerns hygenisation and delivery of the manual form of a companion test which has known validity and reliability in order to employ "stylistic tests" as part of "before and after" research designs or in training evaluation.

Because of the confusion it is essential to distinguish between SPC2 and SPCP2 (which are compatible with a very large body of work, chiefly in Europe by several independent researchers often using different but equally defensible and intercomparable scoring schemes, extending over some 12 years) and other forms which, doubtless have merit, but are apparently incompatible with a North American population. These other forms also suffer from an inflexible scoring scheme and, unless special precautions are taken, would be difficult to rescore as desired.

7. Some Rules Not Mentioned in the Documentation of Systems

In the context of "CASTE and THOUGHTSTICKER" it is noted in the documentation and earlier in this report that any topic or "shared concept" must be attached, directly or indirectly, to a working model. However, it is well worth underlining this essential point.

In addition, a few more authoring rules are needed to render a costly and powerful system free of its hardware limitations. If these rules are satisfied then CASTE and THOUGHTSTICKER become valuable tools of a novel technology. If not, the best authoring possible will fail to provide the user with an image of the internal organisation and these systems will not live up to the claims made for them.

These rules are very commonsensical if the underlying theory is kept in mind but did not become obvious to me (a primary theorist) until it was possible to use the most recent version (that is, C/CASTE/1.0 as delivered) in order to author and scrutinise actual material, for example, statistics).

Hence, apart from the already noted condition, that any shared concept (or topic) must be associated with one or usually many executable model for demonstration, simulation and evaluation, the following restrictions, chiefly if not entirely due to hardware limitations, are mandatory (possible avoidence mechanism are, so far as possible), noted below.

C/CASTE/1.0 operates on a master CASTE machine, an aim and a topic machine. The aim and topic machines act independently, except for interrupt and the passage of necessary signals.

(1) It must be possible for a user to compare and to contrast and independently manipulate the aim and topic machines. Due to screen capacity and sensible visibility the comparison and contrast must, to the user, be simultaneous.

So, for example, if a written description is displayed via these machines (an alternative way is a higher definition slide display), then this description cannot occupy more than one screen of text or low definition graphics.

(2) The same comment applies, but without the slide option, to demonstration, explanation, simulation or evaluation use

of models.

(3) One exception is possible; topic models may reasonably be segmented, if necessary, into mutually comparable parts. This is a difficult and not initially recommended process; it places a considerable burden upon the author and unless the segments are very clearly indexed, is likely to fail.

(4) To each shared concept or model there must, whatever else, be a slide showing the immediate neighborhood in a mesh, of the topic in question.

(5) There must be, available to the user, an image and preferably a graphic image, of the entire entailment mesh.

(6) Anticipating the proposed systems CASTE 1.1 and CASTE 1.2, the assignments of the aim and topic machines may be to accept models for an aim topic or shared concept and some other topic model in the cluster that any user can choose or in the case of CASTE 1.1 and CASTE 1.2 the topic models related by an analogy or a generalisation. In fact, (in this case) the differences and similarities are displayed on the Master CASTE machine. As a matter of fact, there is not much difference (at any rate from a users point of view). But, obviously, the business of comparison and contrast simultaneously is brought into focus.

(7) Topic names are best restricted to at most 40 characters, otherwise overwriting is likely to occur.

(8) Usually, restriction (7) is of small consequence. However, I have found it nonsensical in team authoring where one author, say A, "thinks this..." and another, say B, wishes to say "thinks that...", where "this" and "that" are lengthy.

(9) Such statements can and must be truncated.

These rules became evident to me only after using the demonstrative materials. Many of the topics in these (including those authored by myself) fail to satisfy the basic conditions set out (although, by slight rearrangement, they could readily do so).

8. Immediate Proposals for development of the existing systems

Since the proposals concerned have been submitted in draft form and their receipt has been acknowledged, it would be verbose to recapitulate their content. It is, however, worth noting that they are 3 in number, (a), (b) and (c) below.

(a) A proposal to augment C/CASTE/1.0 into CASTE 1.1 which embodies practicable handling of analogy and generalisation as well as most forms of negation or exclusion; later, into CASTE 1.2 which enhances construction of more comlex models and their configuration in an appropriate CASTE compatible form. The last augmentation is accomplished by using Jaworski's ABL/W/4 as a result of which any rational person, neither having nor desiring fluency in Microsoft BASIC 5.3 is able to manufacture models that are specified in rational language and transformed into code acceptable by the existing, or any other systems.

Enhancement of THOUGHTSTICKER 1.0 in a similar fashion, for facile use by experienced authors or teams of them.

(b) Upgrading TDS 1.0 into a system with proper recording and replay capabilities and a proper incorporation of tactics. In addition, it is proposed to provide more elaborate and user friendly display facilities.

(c) The construction of a manually administered and a computer administered version of a "stylistic test" or "Quantifiable learning, innovation and recall system: SRC2" which is compatible with SPC2 (already delivered). Since this test (often known as the "Smugglers Test" is based upon an isomophic entailment mesh, the mutual validity with SPC2 is established. Further, practical experience with the earlier manual versions has shown its high mutual reliability over some 600 respondents. Hence, it can be confidently used in before and after type studies of conceptual style, especially if the experimental design of SPC2 first SRC2 next and vice versa is possible.

9. An overview of theoretical work undertaken and disseminated

A considerable body of theoretical research has been performed under this contract. The rubric "theoretical" is meant to cover the productions of algorithmic specification and, for example, the algorithms underlying the proposed developments noted in Section 8. Further, it has been possible to provide at least one embedding of Lp in the topological domain and as a result to furnish a more readily implemented and more powerful theory of knowledge and rational belief.

Much of the content of the theoretical work is contained in a memoradum, circulated in September 1985 to give an "in house overview" and replete with references to people ideas or events. Theoretical work prior to that has been published, with proper acknowledgement, in an invited review paper of Conversation Theory and its protologic Lp in the journal ESTJ (vol. 32, no 1, pages 3 - 40). A further innovation "active content of a learner", appears in the O/OACTE/1.0 documentation.

The memorandum is in the process of conversion by editing, refinements and the elimination of purely "in house" allusions into a lengthy paper to appear in the International J Man Machine Studies which has gone through several drafts. Of these drafts the final one will be attached to this report, the Review Paper as Annex 1 and the Final Int. J.M.M.S. paper as Annex 2 both,noted earlier.

Here, I very briefly summarise the essential discoveries which are, without exception, open to implementation.

In contrast to the previous image of Lp statements as static entailment mesh inscriptions; (albeit animated by such unfolding operations as prune or selective prune or extand or such inferential operations as saturate), there is now an obvious duality of mesh and operation. The "static" mesh images the "dynamic" action of all of these and of several other operations that do, in combination and perpetual operation, image the application, producion and reproduction of all stable personal concepts in a mind and brain. In a computer implementation employing present day machines Application Ap, in any distinct mental organisation is replaced by an application of a more limited kind: namely, the execution, Ex of, topics or shared concepts and the

analogous processes that are responsible for maintaining their coherence and preserving their distinction. The resulting picture thus resembles a flux of activity with attractors and deflectors. From time to time these attractors and deflectors have maxima leading, on the one hand, to bifurcation into parts or on the other hand to a directed behaviour, emerging from a productive and kinetic background.

It is thus legitimate to regard the apparently static mesh as a product, a somewhat artificial product, of dynamic interplay. On the other hand, it is possible to argue that the mesh structure induces the activity. In fact, they are complementary. If there is a mesh and if there are attactive and deflective processes, then both are needed for a proper understanding of this reality.

As refined in Annexe 1 and in Annexe 2; this revised perspective shows an "Artificial" intelligence. But as I have often noted, there is no reason to use the qualifier 'Artificial' in the context of this kind of an intellect. Perhaps "non standard" intellect, or "human only if trained to be human intellect", would capture the intended meaning.

10. Other Deliverables

Several other items have been and/or/are in the process of delivery. These are as follows:

(a) Short segments of video tape made, at the request of Dr. Ed Johnson. These segments are intended for a specific audience. They consist in a brief lecture by Paul Pangaro deliberately (at request) in a "talking head" and "poster board" mode; a demonstration of an early version of Apple II + CASTE, again by Paul Pangaro, also in a requested style, suitable for interpolation in a verbal presentation to a small group.

(b) A primer, requested, particularly, by Dr. Ruth Phelps and an associated 4 tape presentation consisting in interviews, explanations, demonstrations and the like, directed by Bernard Carver with the cooperation of other staff. As in the case of SPCP and SPCP2 some confusion arose as the result of the contract extension and my own rather lengthy hospitalisation. On the one hand, I drafted a film/tape/script and started work on a primer derived from it and intended to augment it as a reminder booklet. Upon my return Bernard and I worked briefly on the script which is, by entertainment or documentary standards, the basis for a low cost production item. However, under the circumstances, its cost is too high and other tapes have been made.

Meanwhile, also, David Mitchell had been working on a primer which was nearing completion and is now finished. Consequently, it was pointless to extract an appropriate form of primer from my script. For the ecord, however, I shall attach a copy of the "Marked up" script "as it was left" and thus without tidying.

11. Dissemination of Knowledge

From the outset the importance of disseminating knowledge and findings by refereed papers book chapters and conference proceedings, has always been emphasized. Consequently, a great deal of effort has been expended in presenting carefully placed publications, symposia and seminars.